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Ecotoxicology as a tool for soil sustainability: Agrochemicals and Veterinary Pharmaceuticals in Brazil

A ecotoxicologia como ferramenta de sustentabilidade do solo:Agroquímicos e produtos farmacêuticos veterinários no Brasil

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ABSTRACT

Brazil is considered the world's granary, as consequence there is the use of the use of some agricultural inputs as agrochemicals and veterinary pharmaceuticals. These compounds may represent a risk to the environment and so to the soil. This review presents an overview of the scientific research on agrochemicals and veterinary pharmaceuticals products conducted in Brazil, especially regarding to soil ecotoxicology as a tool for soil conservation. Currently there are 3149 documents available in the Scopus Database using the keywords "soil ecotoxicology" where Brazil represents around 4%. Concerning the publications on soil ecotoxicology in Latin America Brazil has been publishing the most. Regarding the agrochemicals, Brazil is ranking the 8th place with 69 documents of 1190. About the veterinary pharmaceuticals, Brazil is ranking the 11th place, where the 1st publication was 21

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years after the 1st paper published from Denmark. Anyway, the Brazilian Network of Terrestrial Ecotoxicology now a days consists of almost 292 people twice bigger than was in 2016, they are mostly situated in South and Southern of Brazil. Agriculture and livestock farming intensification increase the use of pesticides and veterinary pharmaceuticals in Brazilian soils, so they are gaining relevance in the studies due the extent to which they are practiced. Therefore, it should be the major environmental concerns for researchers and the governmental.

Keywords: Soil invertebrates, soil contamination, pesticides, veterinary medicinal products, soil conservation, soil sustainability, terrestrial ecotoxicology.

RESUMO

O Brasil é considerado o celeiro do mundo,como consequência, há o uso de alguns insumos agrícolas como agroquímicos e produtos farmacêuticos veterinários. Estes compostos podem representar um risco para o ambiente e, portanto, para o solo. Essa revisão apresenta uma visão geral da pesquisa científica sobre agrotóxicos e produtos farmacêuticos veterinários realizados no Brasil, especialmente no que se refere à ecotoxicologia do solo como ferramenta para a conservação do solo. Atualmente, existem 3149 documentos disponíveis no banco de dados Scopus, usando as palavras-chave “ecotoxicologia do solo”, onde o Brasil representa cerca de 4%. Quanto às publicações sobre ecotoxicologia do solo na América Latina, o Brasil tem publicado maior. Em relação aos agrotóxicos, o Brasil ocupa o oitavo lugar com 69 documentos de 1190. Sobre os produtos farmacêuticos veterinários, o Brasil ocupa o 11º lugar, sendo que a primeira publicação ocorreu 21 anos após o 1º trabalho publicado da Dinamarca. De qualquer forma, a Rede Brasileira de Ecotoxicologia Terrestre hoje em dia é composta por quase 292 pessoas duas vezes maior do que em 2016, a maioria delas está situada no Sul e Sudeste do Brasil. A intensificação da agricultura e pecuária aumenta o uso de agrotóxicos e produtos farmacêuticos veterinários em solos brasileiros, de modo que eles estão ganhando relevância nos estudos devido à medida em que são praticados. Portanto, deve ser a principal preocupação ambiental dos pesquisadores e do governo.

Palavras-chave: Invertebrados do solo, contaminação do solo, pesticidas, medicamentos veterinários, conservação do solo, sustentabilidade do solo, ecotoxicologiaterrestre.

1 INTRODUCTION

Since the 90's the food production and global hunger have been increased public concern about the damage of the earth’s ecosystem, one example of this it is the Earth Summit, created as a response for Member States to cooperate together internationally on development issues (SNAPP & POUND, 2017). Not only, the United States Congress (1990), have define sustainable agriculture as “an integrated system of plant and animal production practices having a site-specific application that will, over the long-term, satisfy human food and fiber needs; enhance environmental quality and the natural resource base upon which the agricultural economy depends; make the most efficient use of nonrenewable resources and on-farm ranch resources, and integrate, where appropriate, natural biological cycles and

controls; sustain the economic viability of farm operations; and enhance the quality of life for farmers and society as a whole".

The food-producing chain plays a very important role in the Brazilian economy, where it is considered one of the largest agricultural producer and exporter worldwide (PIGNATI et al., 2017). However, differently from the other sectors of the economy, the growth of plants and animals, environmental disturbances, soil conditions and climate, considering also cultural factors, turn food production an intense local process (MOURA et al., 2018), which means that the use of some agricultural inputs to improve and keep the production, as agrochemicals and veterinary pharmaceuticals are needed. Regarding these inputs, the impact on the environmental quality on food-producing in rural and extensive farming systems has been increasing as fast as ever, mainly contaminants such as agrochemicals and veterinary pharmaceuticals (BRAMBILLA & TESTA, 2014).

The data obtain from the last Census of Agriculture in 2017, identified in Brazil a total area of 350,253,329 hectares which are actively producing, in relation to the last Census of Agriculture in 2006, this area has grown at 5% rate, about 16.5 million hectares (IBGE, 2017). So far, since 2008 Brazil has being considered one of the largest consumers of the world's agrochemicals (PIGNATI et al., 2017). The last IBGE Census investigated whether the farmers used agrochemicals during 2017. The data showed an increase of about 20.4% in relation to the Census of 2006 (IBGE, 2017). Bombardi et al. (2016) carried out a compilation of the cases notified to the Ministry of Health about pesticide intoxication from 2007 to 2014 showing more than 25 thousand cases. However, it is estimated that for each case notified there are 50 others non-notified, i.e. 1.250.000 cases of intoxication in 8 years.

In terms of use, Brazil is ranking the 8th position when it is related to pharmaceuticals. This position represents almost 2.45% of the whole market and, it is expecting to move to 5th place in 2021, according to IQVIA data (SUNDUSFARMA, 2017). According to *Sindicato Nacional daIndústriadeProdutospara Saúde Animal*, National Union of the Animal Health Products Industry (SINDAN, 2018), the therapeutic classes most commercialized in 2017 were the antiparasitic (27.2%), biological (23.3%), antimicrobial (15.2%), supplements and additives (12.2%), others (11.4%) and therapeutic (10.7%). An implication of this it is the large amount of veterinary antibiotics that reach agricultural fields by manure fertilizing, which might lead to an increased abundance and transferability of antibiotic-resistance determinants (BOXALL et al., 2004; JECHALKE et al., 2014;MACCARI et al., 2016; YOPASÁ-ARENAS & FOSTIER, 2018; PARELHO et al., 2018; ZORTÉA et al., 2018).

The widespread exposures to agrochemicals and residues of pharmaceuticals are considered a public health problem (STARLING,AMORIM & LEÃO, 2018). The exposure may occur through aspirations, eye/dermal contact, directly ingestion or in contaminated food or water with residues from agrochemicals (RIGOTTO, 2011; DONKOR et al., 2016; TOMIAZZI et al., 2018). Not only, depending on their persistence and toxicity, it may interfere in the basic ecosystem processes, such as reduction of microbial activity, selection of resistant species, and altering the dynamics of edaphic fauna populations, reflecting important processes in terrestrial ecosystems such as cycling of nutrients, decomposition of organic matter and improvement of chemical and physical attributes (BARETTA et al., 2011; IBAMA, 2010; MALLMANN et al., 2018), these compounds represent a risk to the soil. Once the environmental regulations in Brazil are mainly for pesticides, which must be monitored for the purpose of drinking water quality standards (BRASIL, 2011), about other contaminants of emerging concern there are still no legal requirements regarding this control in order to prevent or minimize the discharge in to the environmental (MACCARI et al., 2016; STARLING,AMORIM & LEÃO, 2018; BOCHNER, 2015; SEGAT et al., 2015, 2019), such as soil.

One way of evaluating the adverse effects of pollutants in soil organisms is conducting toxicity tests, which can be used to determine an acceptable concentration of a test substance in the soil. Ecotoxicological tests are tools capable of reflecting the effectiveness of remediation actions, evaluating the quality of a contaminated soil (ZAGATTO, 2006). Soil ecotoxicology has been motivated by the increasing global awareness on environmental issues. Northern Hemisphere has been leading the research, though the number and quality of contributions from the Southern Hemisphere are increasing quickly in this science branch, especially the Brazilian (NIEMEYER, CHELINHO & SOUSA, 2017). Niva et al. (2016), pointed out that in Brazil the most active groups in soil ecotoxicology often consisted of scientists from governmental research stations, universities or groups that have aquatic ecotoxicology background.

This chapter aims to present an overview of the available published studies and active groups on soil ecotoxicology with pesticides and veterinary pharmaceuticals conducted in Brazil by (or in collaboration with) researchers. We do not intend to make an extensive review but a brief of what has been done over the last years and what should be the next steps in soil ecotoxicology and environmental conservation regarding pesticides and veterinary pharmaceuticals.

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2 MATERIALS AND METHODS

The information was gathered mostly from available database Scopus Database and information gotten from a network group called *Rede Brasileira de Ecotoxicologia Terrestre* (Brazilian Network of Terrestrial Ecotoxicology). The keywords used to search included: soil ecotoxicology, pesticides and veterinary pharmaceuticals, and sometimes limiting the search results to Brazil country, e.g. [TITLE-ABS-KEY (soil AND ecotoxicology)] AND [LIMIT–TO (AFFIL COUNTRY, “Brazil”)]; [TITLE-ABS-KEY (soil AND ecotoxicology AND pesticides)] AND [LIMIT–TO (AFFIL COUNTRY, "Brazil")]; [TITLE-ABS-KEY (soil AND ecotoxicology AND veterinary AND pharmaceutical)] AND [(LIMIT-TO (AFFIL COUNTRY, "Brazil")]. The publications were from over time until March 2019. The documents types included were: articles, articles in press, book chapter, reviews, conference papers and editorial documents. The graphics were made in the Excel Program or directly by Scopus website with the data obtained from the search.

3 OVERVIEW OF THE TERRESTRIAL ECOTOXICOLOGY OF BRAZIL IN WORLDWIDE

Currently there are 3149 documents available in the Scopus Database using the keywords “soil ecotoxicology”. Among them, 126 documents published were from Brazil, is representing around 4% of it and is ranking on 12th (data from beginning from 1977 to the beginning of March 2019). The major part of the published documents are articles (Figure 1). Concerning Brazilian publications on soil ecotoxicology in Latin America, Niemeyer, Chelinho& Sousa(2017) presented that the largest number of the total scientific production contributions were originated in Brazil, which represents around 55%.

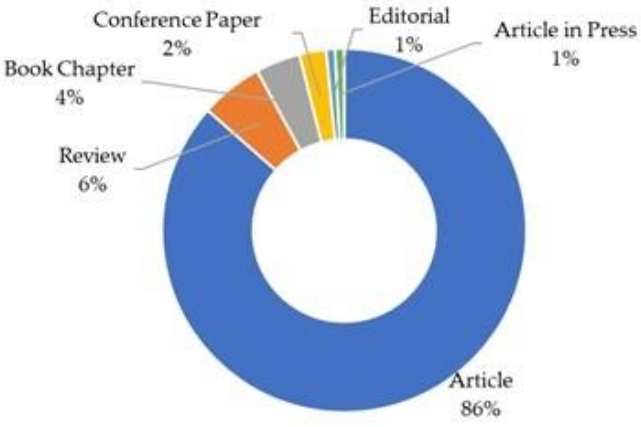

Figure 1. Types of documents published from Brazil.

Despite the good ranking worldwide on soil ecotoxicology publications, when it was add the word pesticide in the search, it came that Brazil is ranking the 8th place with 69 documents of 1190 i.e., one third of China, which is the 1st on ranking, presenting 197 documents. The first document published concerning soil ecotoxicology was in 1977 from Food Agriculture Organization of United Nations (WINTERINGHAM, 1977) bringing out the relevance of to identify indicator organisms easily to observe their biological sensitivity. The firth document published in Brazil concerning pesticides it was in 1996 when Ichinose et al. tested the lethal effect on the earthworm *Eisenia fetida* in natural and artificial soils (apud NIVA et al., 2016).

But, when it was added the words veterinary pharmaceuticals, Brazil is ranking the 11th place with 7 documents of 131, where the 1st publication was 21 years after, in 1998 by Halling-Sørensen et al. (1998), from Denmark. This paper outlines the different anticipated exposure routes to the environment, the legislation and gives an outline of knowledge of occurrence, fate and effect on both the aquatic and terrestrial environments. Only in 2016, almost 10 years latter Maccari et al. (2016), evaluated the effects of pig manure, from diets incorporating veterinary pharmaceuticals, on survival and reproduction of *Folsomia candida* in subtropical natural soils. Since that time not much is known about the exposure routes of these substances to the environment, showing that this area tail it not being so explore worldwide.

Regardless the low research, there is some concerning about the effects of the application of veterinary medicinal products to livestock, because of the impact in soil organisms and then may retard the degradation of dung on pastures and/or can impact soil organisms (KOOLS et al., 2008; ZORTÉA et al., 2017, 2018; RÖMBKE et al., 2018). Although the European Union required higher-tier tests to give the authorization for veterinary medicinal products even when there are no guidance documents to run it properly and also, they are trying to define where and when a monitoring should be performed (KOOLS et al., 2008; RÖMBKE et al., 2018). At the moment, there are only single-species toxicity standard tests and few field tests available (ADLER et al., 2016; WOHDE et al., 2016) which mean a huge field to explore this area of science.

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4 BRAZIL SOIL ECOTOXICOLOGY AND THEIR RESEARCH ACTIVITIES

The historical overview on soil ecotoxicology in Brazil was very well described by Niva et al. (2016), showing the growth of the soil ecotoxicology community over the years. Currently, the Brazilian Network of Terrestrial Ecotoxicology consists of almost 292 people (SOCIEDADE BRASILEIRA DE ECOTOXICOLOGIA TERRESTRE, 2019) twice bigger than was in 2016, when there were only 90 members (NIVA et al., 2016). That can be seen on Figure 2, where the number of documents have considerable increased in the last years. Nevertheless, in this search this number might be an underestimate grade considering the unpublished studies e.g., thesis, masters, etc.

Niva et al. (2016) showed that majority the active groups are in the south and southeastern regions of Brazil. Those regions are densely populated and economically strong and there is a higher density of scientific and educational institutions.

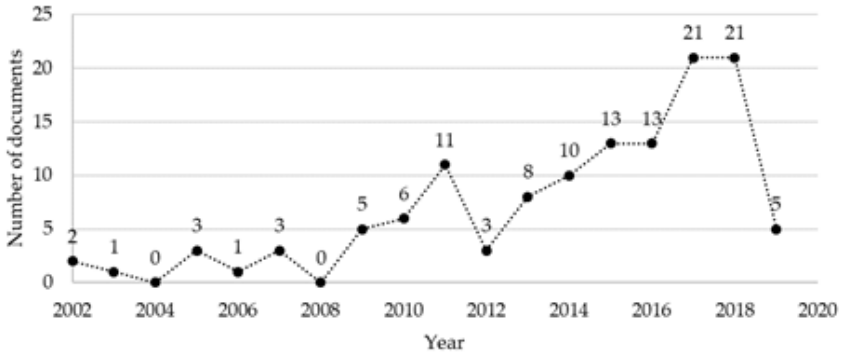

Figure 2. Number of publications of Brazilian research groups, including articles, articles in press, book chapter, reviews, conference papers, and editorial documents.

Most of them are locate in the state of Santa Catarina. In the other hand, the institutions working with soil ecotoxicology are decreasing and/or polarizing. One possible reason for that, is the Brazilian political and economic instability and crises, most part of the documents comes from governmental and educational institutions turning difficult to get resources for science research. Every day, there are more slashes funding for science (there are even some scientific institutes running out of money for basic needs, such as paying electricity bills) (FAPESP, 2018; ANGELO, 2017).

In figure 3 is shown the 10 Brazilian institutions that have published more over the years, which are also the ones that has mostly published in the last few years. However, some institutions are no longer publishing, as UniversidadeEstadual de Londrina (UEL) where the

first publication was in 2010 intitle “Environmental risk assessment of a metal-contaminated area in the Tropics. Tier I: Screening phase”, from Niemeyer et al. (2010) and the last one, with seed dressing pesticides in tropical artificial soil (TAS) in 2014 (ALVES et al., 2014). Also, we could mention the Universidade Federal do Espírito Santo (UFES) that has published a paper in 2011 with diplopods (SILVA SOUZA, ANGELIS & FONTANETTI,2011) and thereafter, the institution has published only a review about diplopods in soil ecotoxicology in 2014 (SILVA SOUZA et al., 2014).

In the other hand, *Embrapa* is the institution that has published the most (Figure 3) all over the years and along the years the publications has increased, having a gap only in 2014 when they had none. The publications are especially in cooperation with other Brazilian institutions and researchers but sometimes with other countries mostly from Europe. The 1st publication was in collaboration with German's institutions and was a review about terrestrial ecotoxicological test methods for the tropics towards the use of pesticides in Brazil (RÖMBKE, JÄNSCH & DIDDEN, 2005). The last publication it was in December 2018 in cooperation with Portugal’s institutions (PARELHO et al., 2018).

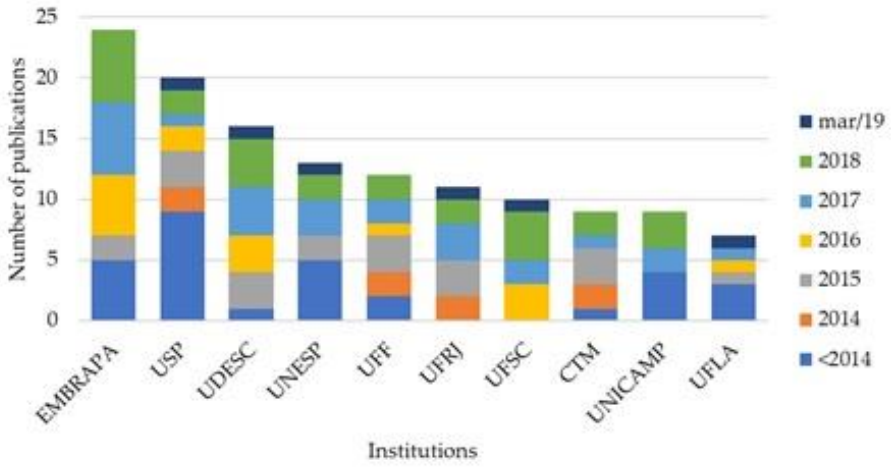

Figure 3. Brazilian institutions publications on Soil Ecotoxicology until March 2019. EMBRAPA: Empresa Brasileira de Pesquisa Agropecuária; USP - Universidade de São Paulo; UDESC: Universidade do Estado de Santa Catarina; UNESP: Universidade Estadual Paulista; UFF: Universidade Federal Fluminense; UFRJ: Universidade Federal do Rio de Janeiro; UFSC: Universidade Federal de Santa Catarina; CTM: Centro de Tecnologia Mineral; UNICAMP: Universidade Estadual de Campinas; UFLA: Universidade Federal de Lavras.

When it is seen the documents by products published about soil ecotoxicology in Brazil, looking just at pesticides and the veterinary pharmaceuticals, there are 78 documents

published, mostly are with insecticides (30), follow by herbicides (23), fungicides (18) and veterinary pharmaceuticals (7) (Figure 4).

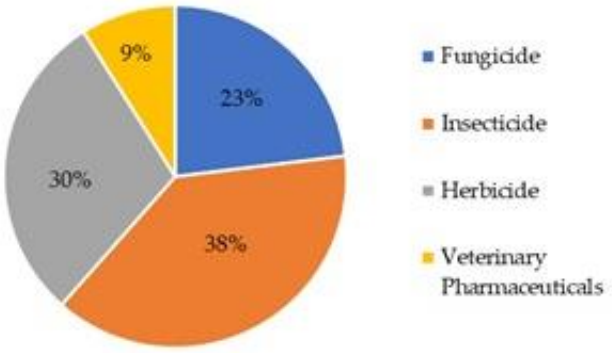

Figure 4. Number of documents generated by evaluated products.

The figure 5 shows the number of documents only about pesticides published in Brazil by year. The first three were in 2005, regarding terrestrial ecotoxicological test methods for the tropics (RÖMBKE, JÄNSCH & DIDDEN, 2005), effects of herbicide and insecticide in soil fauna (ANDRÉA & PAPINI, 2005; PEREIRA et al., 2005). In the other hand, only in 2016 came out the 1st publication of pharmaceutical veterinary in Brazil, about the ecotoxicological effects of pig manure contaminated with antibiotics on *F. candida* in subtropical Brazilian soils. This study, no significant effects derived from the antibiotics were detected due to their low residues in the manures (MACCARI et al., 2016). The last publication was released in January 2019 about nanoemulsions containing Mancozeb and Eugenol formulations were evaluated through cytotoxicity, genotoxicity and ecotoxicity assays, thus Eugenol was the safest formulation to use in agriculture, as it did not cause reduction of cell viability, reactive oxygen species production and DNA damage and did not present ecotoxicity to *F. candida* (GÜNDEL et al., 2019).

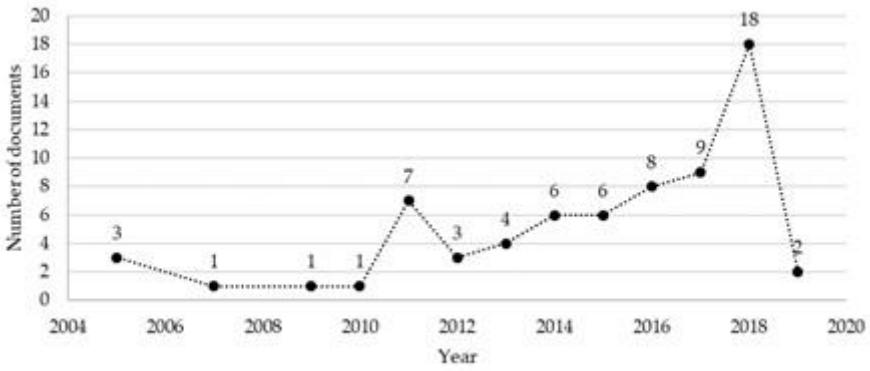

Figure 5. Number of documents about pesticides published by year from Brazil.

Regarding to the pesticides, the institutions being active in soil ecotoxicology and their research activities (Figure 6) and veterinary pharmaceuticals the active group working on it is mostly from Universidade do Estado de Santa Catarina (UDESC), that works with cooperation with others institutions from Rio Grande do Sul, Portugal and São Paulo.

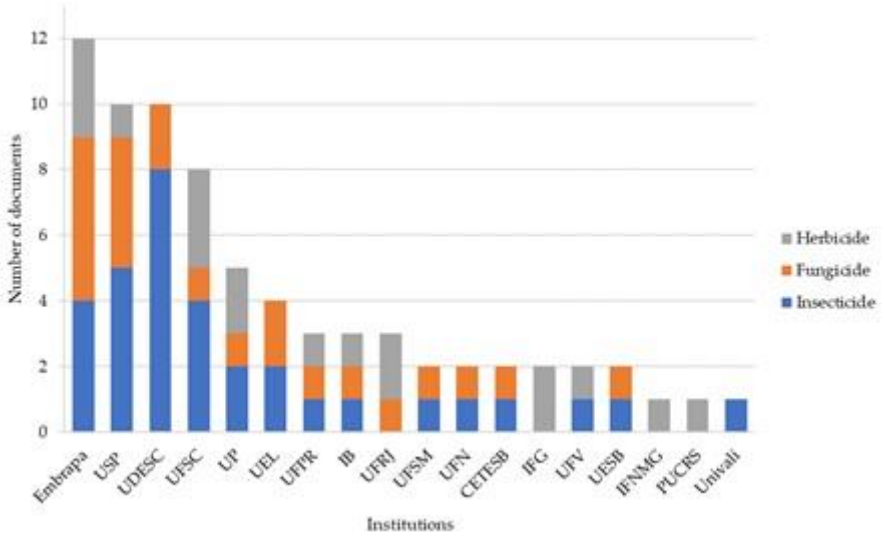

Figure 6. Number of documents published by Brazilian institutions about pesticides in soil ecotoxicology. Embrapa: Empresa Brasileira de Pesquisa Agropecuária; USP: Universidade de São Paulo; UDESC: Universidade do Estado de Santa Catarina; UFSC: Universidade Federal de Santa Catarina; UP: Universidade Positivo; UFRRJ: Universidade Federal Rural do Rio de Janeiro; UFPR: Universidade Federal do Paraná; IB: Instituto Biológico; UEL: Universidade Estadual de Londrina; UFSM: Universidade Federal de Santa Maria; UFN: Universidade Franciscana; IFNMG: Instituto Federal do Norte de Minas Gerais; CETESB: Companhia Ambiental do Estado de São Paulo; IFG: Instituto Federal Goiano; PUCRS: Universidade Católica do Rio Grande do Sul; UFV: Universidade Federal de Viçosa; UESB: Universidade Estadual do Sudoeste da Bahia; Univali: Universidade do Vale do Itajaí.

5 CONCLUSIONS

Agriculture and livestock farming intensification increase the use of pesticides and veterinary pharmaceuticals in Brazilian soils, so they are gaining relevance in the studies due the extent to which they are practiced. Therefore, it should be the major environmental concerns for researchers. This is relevant in areas such as the environmental risk assessment, regulations to new pesticides and veterinary pharmaceuticals, where more research is needed in order to fully implement a true Environmental Risk Assessment in Brazil. It must be

assured that consequences of legal actions are implemented. This should be done in combination with, e.g., training of regulators and farmers or on imposing quality assurance measures in laboratories. The government should support the development of soil ecotoxicology in their scientific institutions by financially supporting programs in this area. Thereby providing the soil quality and environmental integrity and then the ecosystem services may be preserved for future generations.

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